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IFPRI Discussion Paper 00749

February 2008

Seed Value Chains for Sorghum and Millet in Mali

A State-Based System in Transition

Lamissa Diakité, Institut d'Economie Rurale
Amadou Sidibé, Institut d'Economie Rurale
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Environment and Production Technology Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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FINANCIAL CONTRIBUTORS AND PARTNERS

IFPRI's research, capacity strengthening, and communications work is made possible by its financial contributors and partners. IFPRI gratefully acknowledges generous unrestricted funding from Australia, Canada, China, Denmark, Finland, France, Germany, India, Ireland, Italy, Japan, the Netherlands, Norway, the Philippines, Sweden, Switzerland, the United Kingdom, the United States, and the World Bank.

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Published by

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ABSTRACT

This paper reviews the structure and performance of the sorghum and millet seed sector in Mali. The Sahel is the origin of pearl millet and sorghum, seed selection and management of these crops is embedded in local cultures, and most producers of these crops are subsistence oriented. Despite seed sector reform, no certified seed of these crops is sold in local markets and farmers prefer to rely on themselves or each other for seed. The dominant source of certified seed is the national seed service. Certified seed is multiplied by contracted farmers and seed producer groups, and supplied to farmers through farmers' associations, development organizations, and extension services. The informal sector supplies farmers with non-certified seed directly and indirectly through village grain markets. There is no consensus about whether it is lack of effective demand or supply that constrains farmer use of certified sorghum and millet seed, but researchers generally conclude that the process of certifying seed is too lengthy, some mechanism must be established for production and trade of locally-adapted landraces, and Mali's highly structured farmers' associations could play an even stronger role in testing and promoting demand for certified seed. Recommendations have included the use of small packs and seed auctions where market infrastructure is sparse, and in more commercialized areas, involvement of agro-input dealers, shopkeepers and traders. Still, estimated adoption rates for improved millet (under 10 percent of crop area) and sorghum seed (under 20 percent of crop area) could be as high as can be expected in this challenging natural environment and institutional context.

Keywords: seed, formal sector, informal sector, millet, sorghum, Mali

ACKNOWLEDGMENTS

The authors thank anonymous reviewers of an earlier draft for their helpful comments, as well as plant breeder Eva Weltzien, economists Latha Nagarajan and Leslie Lipper, and interpreter Aimée Niane for their assistance on numerous technical points. This research is funded by the Food and Agriculture Organization of the United Nations and builds on an earlier project supported by the International Fund for Agricultural Development.*

* This paper draws heavily from documents written in French by the first two authors, rephrased and expanded by the third and fourth authors.

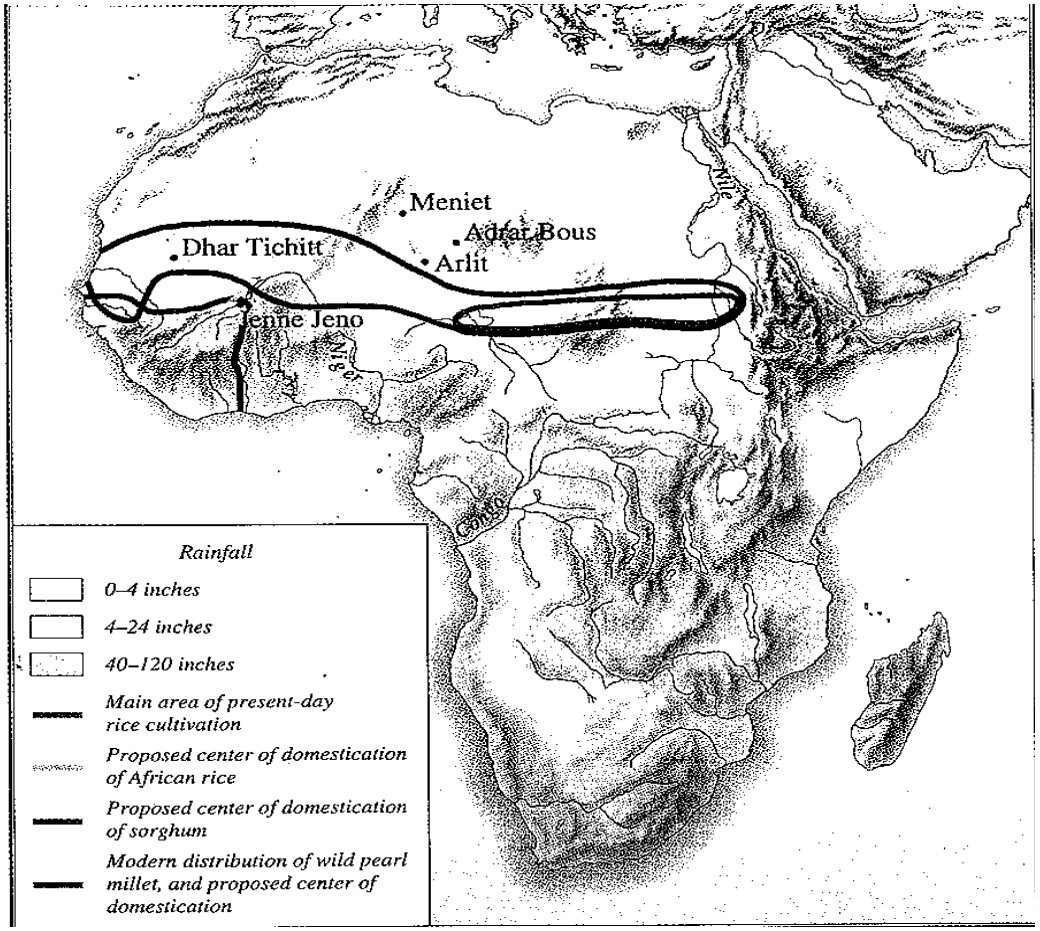
ABBREVIATIONS AND ACRONYMS

Abbreviation or Acronym	French	English
AOPP	Association des Organisations Professionnelles Paysannes	Association of Farmers' Professional Organizations
ASSEMA	Association Semencière du Mali	Seed Producers Association of Mali
BNDA	Banque Nationale de Développement Agricole	National Agricultural Development Bank
CNEV	Comité National des Espèces et Variétés	National Species and Varieties Committee
CNS	Conseil National des Semences	National Seed Council
CSV	Cellule Semencière Villageoise	Literally, "Village seed cell," meaning formally-established, groups of farmers organized to multiply seed
DNAMR	Direction Nationale de l'Appui au Monde Rural	National Direction for Support to Rural Development
FAD	Fonds Africain de Développement	African Development Fund
ICRISAT	Institut International de Recherche sur les Cultures pour les Tropiques Semi-arides	International Center for Research in the Semi-Arid Tropics (ICRISAT)
IER	Institut d'Economie Rurale	Institute of Rural Economy
IPR	Institut Polytechnique Rural	Rural Polytechnic Institute
LABOSEM	Laboratoire Central des Semences Végétales	Central Laboratory of Plant Seeds
NGO	Organisation non-gouvernementale	Nongovernmental organization
OPSS	Opération Production Semences Sélectionnées	Operation Production Improved Seed
ORIAM	Réseau des Opérateurs d'Intrants Agricoles du Mali	Malian Network of Agri-Input Dealers
PAFISEM	Projet d'Appui à la Filière Semencière	Project to Support the Seed Value Chain
PASAOvP	Programme d'Appui aux Services Agricoles et aux Organisations Paysannes	Program to Support Agricultural Services and Farmers' Organizations
SSN	Service Semencier National	National Seed Service
UNDP	Programme des Nations Unies pour le Développement	United Nations Development Program
USC-Canada	Le Comité du Service Unitaire du Canada	Unitarian Service Committee of Canada
WASNET	Réseau Ouest Africain des Semences	West African Seed Network

1. INTRODUCTION

Millet and sorghum are known to have originated within a vast swath that stretches across the African continent along the Sahel, the border of the Sahara (Figure 1).[2]

Figure 1. Proposed areas of domestication of African rice, pearl millet, and sorghum, and the archaeological regions and sites that have yielded the earliest evidence of indigenous African agriculture



Source: Smith (1998, 108).

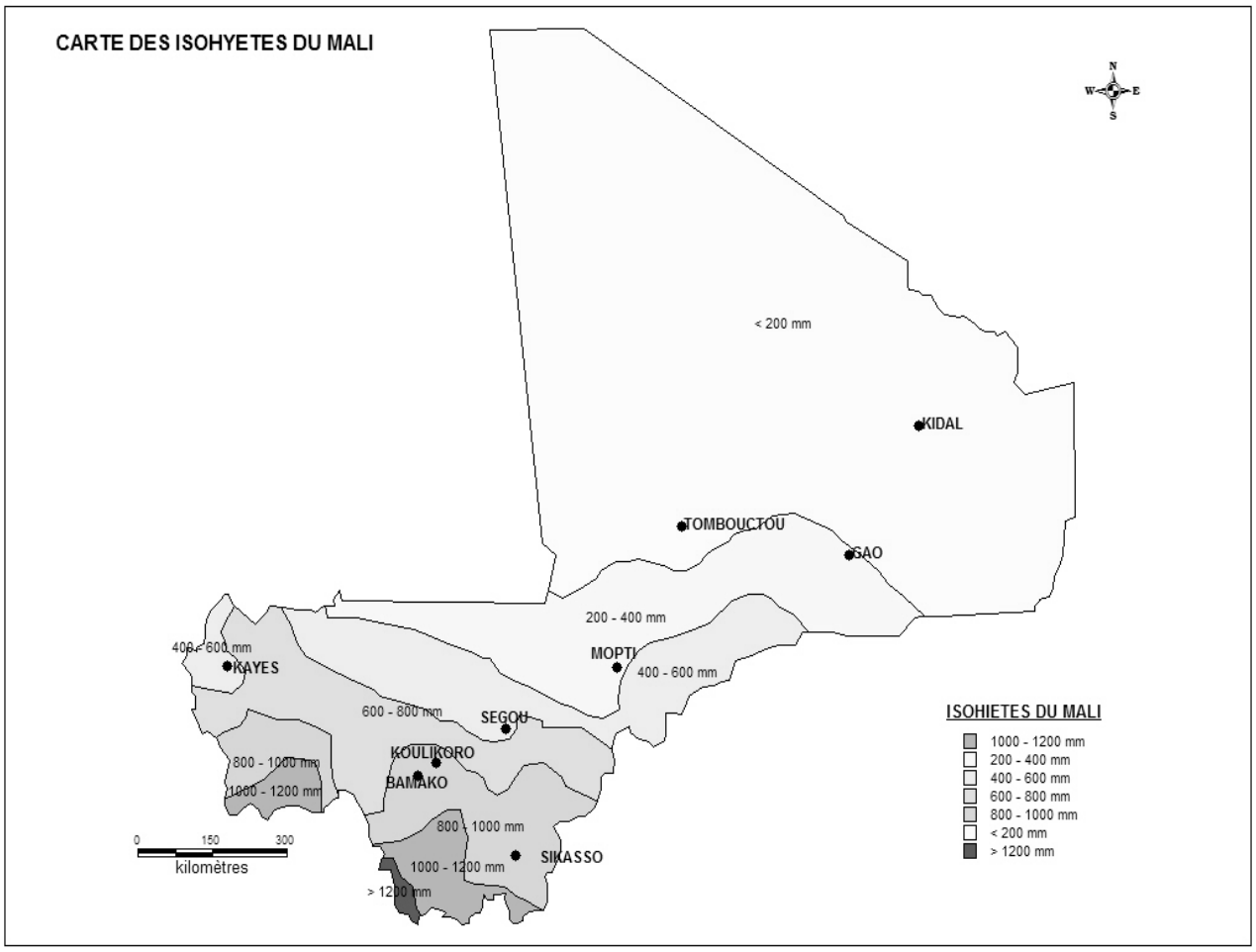
[2] African rice (*Oryza glaberrima*) is the third major indigenous cereal that originated here in a more limited area.

The swath, now situated in the desert, was then savannah (Smith 1998). Harlan (1992, 184) refers to the geographic origin of these crops as "non-centric" because domestication activities appear to have occurred at several locations. Pearl millet is one of the most drought-resistant of the savannah crops and dominates along the desert fringe (Harlan 1992). Archaeological evidence suggests that economies based on cattle, goats, sorghum, and pearl millet were established in this region between 5,000 and 3,000 years ago (Smith 1998).

Thus, Malian farmers have accumulated knowledge of millet and sorghum seed over the centuries. Today sorghum and millet are the major crops of Mali, produced in an agricultural sector that is almost entirely rainfed. Of the area planted to food crops under rainfed conditions (millet, sorghum, rice, maize, groundnuts, and cowpea), millet represents 40 percent (about 1.5 million hectares) and sorghum 21 percent (about .8 million hectares) of the total. Millet yields average only .66 ton per hectare, and sorghum yields average .89 ton per hectare. By comparison, rice yields average 1.7 tons per hectare, and maize yields average about 1 ton per hectare (based on data reported in Touré et al. 2006).

The West African semiarid tropics has been subdivided into the Sudanian, Sahelo-Sudanian, and Sahelian zones based on rainfall probabilities (Matlon 1990; Sanders et al. 1996). At the southwestern tip of Mali, annual rainfall reaches 800 mm in the Sudano-Guinean zone. Sorghum, millet, maize, cowpeas, vegetables, and some cotton compose the cropping system of the Sudanian zone, which receives 600–800 mm of rainfall per year. Crops are similar in the Sahelo-Sudanian zone (350–600 mm of rainfall per year), including groundnut and fonio. Toward the north, millet (intercropped with cowpea) and nomadic grazing assume greater importance. In the Sahelian zone, annual rainfall dwindles to less than 350 mm per year. Millet is grown, but transhumance and nomadic grazing dominate. The statistical census of Mali reports that more than 60 percent of the millet in Mali is produced in the regions of Ségou and Mopti, which span the three drier zones. The locus of sorghum production is in the wetter of the semiarid zones, more heavily weighted to the regions of Koulikoro and Sikasso, but including Ségou (see Figure 2).

Figure 2. Administrative regions of Mali with rainfall isohyets



Source: K. Diallo, January 2008

Though accurate data are lacking, it is generally believed that most producers of sorghum and millet in Mali are subsistence oriented. Throughout the longer-term climatic changes experienced in this region and during a more recent history of declining and increasingly variable rainfall,[3] Malian farmers have selected the varieties that continue to perform best in this harsh environment (Traoré et al. 2000).

Local experts generally report, and recent case studies concur, that millet and sorghum seed is the object of village-level exchanges that are, for the most part, nonmonetized (Diakité et al. 2004; M. Goita and M. Hamada of USC-Canada, pers. comm.; Sperling et al. 2006; Traoré 2006). Seed is given, bartered, inherited, and transferred at marriage. Outside the markets, monetized exchanges occur among farmers in the same villages but may be secretive to avoid the social stigma of being without seed. Barter is observed even in local markets, where grain of a known variety may be occasionally sold as seed. Farmers prefer to rely on themselves for their seed because they cannot necessarily depend on other farmers for large quantities, they do not trust seed sources outside their village networks, and some shame is associated with not having seed.

Although resilient, the farmer seed system is not always adequate to meet farmers' needs. Gifts are often token or "symbolic" (Sperling et al. 2006, 49). Estimates suggest that farmers generally obtain about 7–13 percent of their millet and sorghum seed in local grain markets (Diakité et al. 2004; Sperling et al. 2006; Traoré 2006), although the role of local markets in supplying seed can be more important after successive years of poor harvests. Petty vendors of grain in village markets of the San circle[4] reported that they had sold grain to farmers as seed for replanting after the first planting failed to germinate because of a dry spell (Smale et al. 2007). Based on a case study conducted in the Douentza circle, Sperling et al. (2006) report that some farmers dry plant to ensure that the crop will benefit from the first rains, while other farmers replant several times at the beginning of the season.

Yet, despite the publication in 2002 of an official catalog of 25 improved varieties of millet and 50 improved varieties of sorghum that are adapted to a wide range of rainfall levels, the use of certified, improved seed by farmers is very low for these crops. Further, despite years of legislation and policy discussion about the liberalization of seed markets, no certified sorghum or millet seed is as yet visible in weekly village markets (see, e.g., survey summarized in Smale et al. 2007). Most farmers have no access to the varieties bred by research and multiplied within official diffusion channels. At the same time, researchers know relatively little about the range of locally adapted varieties found among farmers.

[3] Sperling et al. (2006) report that meteorological data spanning some 40–60 years reveals a trend toward more acute dry spells than previously known and larger expanses exhibiting arid characteristics (desert expansion) combined with reduced length of rainy seasons. Matlon (1990) has summarized trends in sorghum and millet productivity from 1960 to 1990 in the Sahel, showing that a chronic pattern of lower rainfall levels beginning in the late 1960s was closely reflected in a declining average annual yield for sorghum and stagnating yields in millet. That millet yields did not decline under extreme climatic duress attests to the effectiveness of farmer selection.

[4] A circle (*cercle*) is an administrative designation, a subset of a region, composed of communes, each of which includes numerous villages.

The heavy dependence of Malian farmers on their own seed system for sorghum and millet varieties is therefore easy to comprehend, but the implications for seed security and productivity are discouraging. In an attempt to understand the apparent disjuncture between the formal and informal systems for sorghum and millet seed, this paper summarizes current evidence about the actors, institutions, and policies that compose the enabling environment.

The next section summarizes the history of legislation and government policy regarding the seed sector, with particular reference to sorghum and millet. Section 3 describes the actors (organizations and institutions) that influence seed sector performance. Section 4 presents some indicators of the performance of formal seed channels for sorghum and millet. Major constraints are summarized in Section 5. The final section presents a summary of recent policy perspectives and recommendations.

2. EVOLUTION OF SEED POLICY AND PROGRAMS

The importance of improved seed in agricultural productivity was recognized in Mali in the early years after independence. Seed policy is based only on the formal system for producing and distributing certified seed. In 1964, a section was established in the Department of Agricultural Research with the aim of regulating the production of improved seed and diffusing it to farmers. With the years of drought experienced during the 1970s, the need for improved seed exceeded the capacity of the seed section. In 1977, the Operation Production Improved Seed (Opération Production Semences Sélectionnées, OPSS) was initiated for the purpose of producing, collecting, stocking, and diffusing seed. Responsibility for regulation remained with the original section.

In 1987, in an effort to find a longer-term solution to the numerous constraints faced in multiplying and diffusing improved seed, the government developed a seed plan that identified the essential features of national policy. Within that framework, the National Seed Service (Service Semencier National, SSN) was established to replace the OPSS, with the strong involvement of farmer seed producers.

The Ministry of Rural Development was restructured in 1996, and programs to support and promote marketing channels and rural credit were designed. A major strategic direction identified by the state was the liberalization of the economy and the encouragement of the private sector. From 1996, it was envisaged that the SSN would gradually transfer all functions to a privatized seed channel. The current formal seed policy derives from the earlier national seed plan but emphasizes the gradual disengagement of the government from production, commercialization, and distribution activities.

In 1974, two seed farms were established with funding from the United Nations Development Program (Programme des Nations Unies pour le Développement, UNDP). The African Development Bank provided support for production of improved seed from 1978 to 1984. This project permitted the establishment of a seed regulatory service and strengthened research on food and oilseed crops, providing buildings and equipment to the OPSS, and the establishing four more seed farms. At the same time, some institutional changes occurred at the Institute of Rural Economy (Institut d'Economie Rurale, IER) that led to the establishment of a regulatory and control section to certify improved seed. A third project, funded by the UNDP and the Food and Agriculture Organization of the United Nations from 1986 to 1994, intervened at several levels in the production of seed of rainfed crops (millet, sorghum, maize, groundnuts, and cowpea). These projects did not succeed in developing a sustainable seed market channel as hoped by the Malian government. Major problems included the inability to establish (1) an efficient, decentralized system for seed regulation and certification; (2) an appropriate credit system; and (3) a constant supply of certified seed for farmers. The government requested additional support from the

African Development Fund (Fonds Africain de Développement, FAD) to build on the lessons learned from the previous projects and organize a stronger initiative.

The project that resulted, called the Project to Support the Seed Value Chain (Projet d'Appui à la Filière Semencière, PAFISEM), is described in a document prepared by the FAD (2001). The document states that for the project to attain its objectives, four types of measures will be undertaken. First, the state will disengage itself from all activities related to the production and commercialization of seed in favor of the private sector and farmer cooperatives. Second, seed production will not necessarily be accomplished in the zones where the varieties will be grown or on state seed farms (whose soils have deteriorated) but in areas of the country that can ensure a steady supply of seed. Third, seed producers will be provided with credit. Fourth, the price of certified seed must cover its cost of production.

The PAFISEM consists of four components: (1) support for the production of certified seed, (2) institutional support, (3) accompanying measures, and (4) project management. Under the project, an initial study was conducted to identify suitable zones for seed production and farmer leaders (Diakité et al. 2005). Villages were selected according to accessibility in all seasons, land availability (without the need to carry on a legal contest by judicial process), technical and management capacity of producers, social cohesion at the village level, and willingness of village leaders to support seed production activities.

According to the FAD document (2001), breeder and foundation seed will be produced and maintained by the IER and other research institutions—such as the Rural Polytechnical Institute (Institut Polytechnique Rurale, IPR) and the International Center for Research in the Semi-Arid Tropics (Institut International de Recherche sur les Cultures pour les Tropiques Semi-arides, ICRISAT)—according to an annual program prepared by the SSN and validated by the National Species and Varieties Committee (Comité National des Espèces et Variétés, CNEV). The SSN will foster and assist farmers to produce first-reproduction registered seed (R1) and second-reproduction certified seed (R2).[5] R1 seed will be produced by farmers on state farms and, in other areas, on farmers' own fields. Farmers will be placed under contractual obligations to improve soil fertility. To produce R2 seed, the previously employed village seed "cells" (Cellules Semencières Villageoises, CSVs) will be replaced by 50 farmer seed producer cooperatives linked to local rural development offices and other projects, of which 20 will produce seed of rainfed crops (millet, sorghum, maize, groundnuts, and cowpea). To support the seed producers, stores will be constructed to stock seed, and credit will be provided to groups and individuals to facilitate the purchase of specialized equipment. Rural Development Operations (Opérations Développment Rurale) and the SSN will continue to assess the demand for seed but will gradually cease to be involved in seed sales. The SSN will also be responsible for a security stock of seed.

[5] Terms as defined by Touré et al. (2006) are found in Table 1.

Mali's seed legislation is described in detail in a report prepared by Christy (2006). Of critical importance for understanding the disconnectedness between formal and informal seed systems is the content of the legislation with respect to the trade of landrace seed and the relationship between the formal and informal sectors. Existing legislation states that only registered varieties may be certified, and the production of seeds for commercialization of other varieties without authorization is forbidden. Needless to say, if this prohibition were not limited to commercial production, both the production and trade of landraces would be illegal.

According to Christy (2006), the latest draft of the national seed law attempts to distinguish between the production of commercial seed and that of other seed. Different degrees of qualification are required depending on the category of seed. Foundation and basic seed can only be produced by research institutions and breeders. Persons who have technical competence can produce seed subject to authorization. Technical approval is required to import or export seed. The draft law does not appear to forbid the production or sale of unregistered varieties. To be certified, a variety must be registered; however, the law does not clearly state that seed must be certified to be sold, only that it must bear a label (*etiquette*) of quality. The draft decree to implement the law explicitly allows only for the production of varieties from the official catalog. Christy also notes that discussions with officials confirmed some ambiguity. Several officials thought that any seed sold should have a basic assurance of germination, while others reported that the legislation was not intended to apply to traditionally produced seed (some of which, as we know, is traded).

Christensen and Cook (2003) state that contradictory laws governing seed have been drafted with little input from farmers groups, professional associations, private seed growers, or the recently established associations for importing seed. They point out that the laws do not provide for "truth in labeling" except through certification, so information about the informal village-level seed trade is not available.

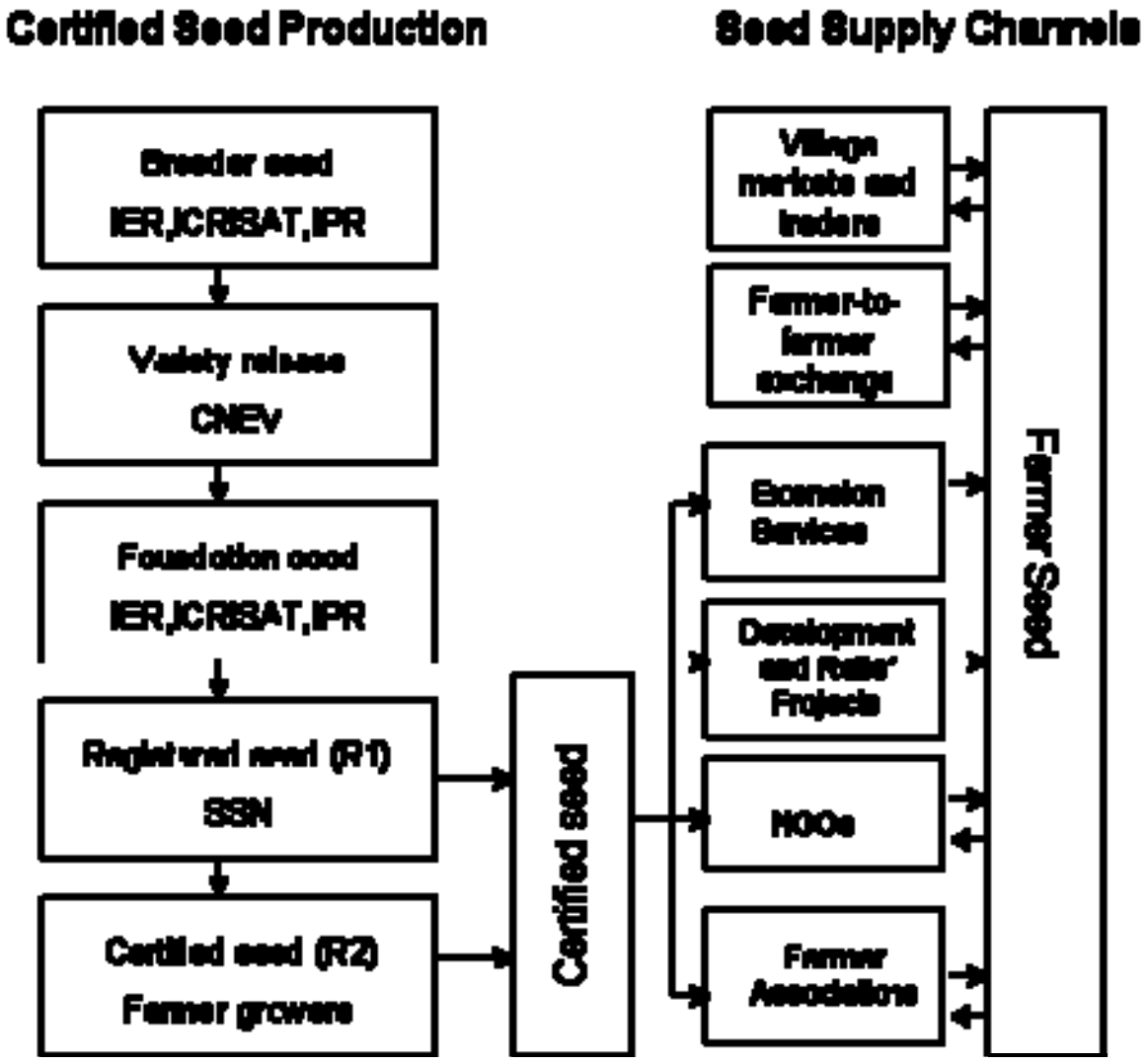
The latest statement of national seed policy is contained in a document reviewed in January 2007 (Ministère de l'Agriculture, 2007), which has not yet been adopted.[6] The draft document has been consulted for the information presented in the sections that follow.

[6] According to the Loi d'Orientation Agricole du Mali dated September 5, 2006, Article 131, Chapter 7, the state and the agricultural profession will define seed policy.

3. STRUCTURE AND ACTORS

Figure 3 shows two channels for producing certified sorghum and millet seed and supplying it to farmers in Mali. The connection between the two channels remains weak. Production of certified seed is accomplished exclusively by formal organizations, while seed supply channels continue to be dominated by the farmer seed system. The depiction in Figure 3 is weighted more toward the period before the PAFISEM began, because it is difficult to assess the extent to which structural changes have occurred during the early phases of seed sector reform.

Figure 3. Map of millet and sorghum seed system in Mali



Source: Adapted from Touré et al. (2006).
Note: A list of acronyms defined in French and English is provided above

Certified Seed Production

On paper, the process of producing seed is well integrated (Figure 3, first panel; fully described by Diakité et al. [2005] and Touré et al. [2006]). The process includes several governmental and semiautonomous institutions, farmers contracted to produce the first generation of certified seed, village cooperatives established to produce the second generation of certified seed, and farmers' professional organizations and unions.

Created in 1991, the National Seed Council (Conseil National des Semences, CNS) is charged with the orientation and implementation of national policy for improved seed. Composed of 14 members representing the principal institutions concerned with agriculture in Mali, the council meets once a year to program the multiplication of foundation and first-generation registered (R1) seed, as well as the distribution of seed for the production of seed among channel actors.

For sorghum and millet, the IER and ICRISAT are charged with the development of new germ plasm and the technology packages of complementary inputs and practices that will enable farmers to earn favorable returns. The IPR is a minor producer of breeder seed that is multiplied into foundation seed. Currently, Mali has six sorghum breeders: four have doctoral degrees (one is with ICRISAT) and two have master's degrees. Among the Malian millet breeders, two have doctorates and one a master's degree; one is with ICRISAT. The average age of all plant breeders in Mali is 50 years, and the total capacity is judged to be insufficient to meet the nation's needs. The IER also manages the security stock of seed and foundation seed in the cold chamber at Sotuba.

When a variety is ready for release, the IER notifies the CNEV through the Ministry of Agriculture. Also created in 1991, the CNEV defines the norms of control and certification of improved seed. Members of the committee then examine the data for all new varieties and conduct a field inspection. Once approved for release, the variety is listed in the national variety catalog. The CNEV has the responsibility for maintaining the seed catalog. The Central Laboratory of Plant Seeds (Laboratoire Central des Semences Végétales, LABOSEM), based in Sotuba, ensures the control and certification of seeds.

The IER and ICRISAT are the major producers of the foundation seed needed to satisfy demand. In Mali, breeder seed is called G0, or *matériel de depart*. Foundation seed, called *semence de pré-base*, is G1 through G4, or first- through fourth-generation seed. The fifth-generation (G5) seed is R1, or registered seed reproduced once. The sixth-generation (G6) seed is R2, or certified seed reproduced twice (Table 1).

Table 1. Improved seed terminology in French and English

Multiplication Generation	Designation (in Mali)	Seed Category (French)	Seed Category (English)
Panicles supplied by research institution	Lignés G0	Matériel de départ	Breeder seed
1st generation	G1	Semence de pré-base	Foundation seed
2nd generation	G2		Foundation seed
3rd generation	G3	Semence pré-base ou de base	Foundation seed
4th generation	G4	Semence de base	Foundation seed
5th generation	RI (G5)	Semence certifiée de 1er reproduction	Registered seed, 1st reproduction
6th generation	R2 (G6)	Semence certifiée de 2e reproduction	Certified seed, 2nd reproduction

Source: Touré et al. (2006, 12).

The SSN was established in 1991 to ensure the production of R1 seed. The SSN is now attached to the Ministry of Agriculture, as is the IER, as a quasi-autonomous organization (*organismes personalisés*). Originally, SSN produced its seed on state farms with relatively high costs. Costs were reduced by transferring production gradually (since 1989) to trained farmers who operate the same lands as tenants. R1 seed is produced on SSN's network of satellite farms by well-trained farmers under the direct supervision of technicians and IER researchers. Studies report that the SSN still produces 85 percent of the R1 millet and sorghum seed in the formal sector through farmers (Diakité and Diarra 2000). Some farmers are also beginning to produce seed on their own land for sale to the SSN. Under the PAFISEM and seed sector reform, SSN's role is meant to shift from seed production to promoting and assisting private (farmer) producers of registered R1 and certified R2 seeds.

To supplement R1 production by the SSN, the village seed producer groups (the CSVs) were initially established to produce R2 seed. CSVs were grouped autonomously or as a function of development projects and nongovernmental organizations (NGOs). Under the PAFISEM, the CSVs are farmer cooperatives that are expected to sell their products.

Today, a total of 137 seed producer cooperatives and associations multiply R1 and R2 seed, distributed across administrative regions and supervised by Agricultural Regional Offices and the SSN. Technical offices in charge of rural development in Mali have been established (Table 2). This structure supports training and decentralized storage facilities and equipment. The National Agricultural Development Bank (Banque Nationale de Développement Agricole, BNDA) furnishes loans to procure supplies, commercialize seed, and cover the costs of certification. The Association of Farmers' Professional Organizations (Association des Organisations Professionnelles Paysannes, AOPP) is also involved in the production of foundation, R1, and R2 seed. Other actors include the Program to Support

Agricultural Services and Farmers' Organizations (Programmes d'Appui aux Services Agricoles et aux Organisations Paysannes, PASAOP), which is also attached to the Ministry of Agriculture.

Table 2. Number of cooperatives and association within agricultural offices

Technical Offices	Number of Cooperatives and Associations	Technical Offices	Number of Cooperatives and Associations
Direction Régionale Agriculture Kayes	9	Office Développement Rizicole Sélingué	1
Direction Régionale Agriculture Sikasso	40	Office Haute Vallée Niger	7
Direction Régionale Agriculture Koulikoro	5	Office Périmètre Irrigué Baguinéda	1
Direction Régionale Agriculture Ségou	10	Office du Niger	5
Direction Régionale Agriculture Mopti	35	Office Riz Ségou	2
Direction Régionale Agriculture Gao	4	Office Riz Mopti	12
Service Semencier National Siège Ségou	6		

Source: Amadou Sidibé

In addition to these institutions, the Seed Producers Association of Mali (Association Semencière du Mali, ASSEMA) was formed in 2003 through the initiative of the African Seed Trade Association. ASSEMA is a member of the West African Seed Network (Réseau Ouest Africain des Semences, WASNET) and the Malian Network of Agri-Input Dealers (Réseau des Opérateurs d'Intrants Agricoles du Mali, ORIAM). Numerous importers and distributors also provide agricultural inputs for cotton and vegetable seeds.

Before the PAFISEM, prices of R1 seed for R2 producers were fixed by the government according to proposals by the SSN. The project's planning document notes that free-market establishment of prices is not immediately attainable but that the project would establish a means for negotiating prices for multipliers of R1 seed at the onset of each cropping season. Prices of R2 seed, previously set by the SSN, were liberalized in 1993. Cereal prices were liberalized in 1991 (FAD 2001).

Seed Supply Channels

Seed supply channels are depicted in the right panel of Figure 3. The SSN is still the most important vendor of registered (R1) seed for cereal crops, although the disappearance of the SSN was planned for 2002 (Diakité et al. 2005). CSVs are the source of R2 seed. Of the SSN production, an estimated 36 percent is bought by NGOs and 31 percent by official agricultural organizations (irrigation projects,

extension services). Twenty percent is divided between development agencies (other than NGOs) and private users (Diakité and Diarra 2000). The CSVs produce the R2 seed, which is collected by the management committees and stocked in the village. Seed producers delivered an estimated 30–40 percent of their production to the management committees of the formal channel, distributing the remainder directly to other farmers instead of through the formal channel. Certified R2 seed produced by the CSVs is now purchased mainly by NGOs and other development agencies.[7]

Several points are worth noting with respect to seed supply channels for sorghum and millet in Mali. First, most of sorghum and millet seed grown is supplied by farmers and is not certified. This system is regulated by social norms and custom rather than formal structures. Touré et al. (2006, 8) state that "there is indeed a very thin market for millet and sorghum seed, especially improved seed" and that "farmers are quite active in diversifying their seed supplies, as long as this does not involve money." Farmer-supplied seed does enter village markets but is more often exchanged among farmers without the use of cash and is handled by some farmers' associations, NGOs, and development and relief projects. Farmer-supplied seed includes local varieties that are landraces as well as recycled, improved varieties.

Second, neither agro-input dealers nor grain traders nor shopkeepers are active in supplying certified seed of sorghum and millet, although they are active in rice and horticultural crops. Thus, at present, the formal seed value chain depicted in Figure 3 has almost no interface with village markets where farmers are active as sellers and buyers. The formal seed production and supply chain is still heavily state based, linked to farmers through agricultural projects, NGOs, and farmer associations.

Third, the relationship between the formal seed chain and the formal grain marketing chain is not clear, hampering the transmission of market-related signals to farmers, such as seed-to-grain price ratios. To our knowledge, the only interface between grain and seed channels occurs in village markets, where farmers and part-time petty vendors sell grain that is suitable as seed in periods of acute seed shortages (e.g., Smale et al. 2007; Sperling et al. 2006).

Fourth, farmers are major actors in *both* the formal seed channel and the farmer seed system. Other major actors in the seed supply channel are NGOs, farmers' associations, and development and relief programs. These are described in greater detail in the following subsections.

Farmer Seed System

Traoré's (2006) case study in the village of Boumbolo, a test village for this research project located in the circle of Tominian, region of Ségou, provides illustrative details about the farmer-based seed system. Although the most frequently cited source of seed was their own harvests, farmers stated that they obtained seed from a wide range of sources within and outside their villages. The village maintains a

[7] It is important to note that these estimates refer to the total seed production and not just to production of millet and sorghum seed. Further, data have not been fully updated.

historical social relationship with certain villages in Burkino Faso, so that farmers may procure seed as far as 50 km away. Among all sources of seed mentioned by farmers (each farmer had several sources), local markets occurred with a frequency of 11 percent. Purchases also occurred in villages for leguminous crops that do not store well, but rarely for cereals. Farmers mentioned cases in which grain purchased as food was tested as seed. According to farmers, market purchases not only have the disadvantage of relatively high costs but also carry uncertainty about variety traits, seed quality, and availability when it is needed. Farmers confirmed that seed provision from their own harvests has the disadvantage that poor characteristics (such as vulnerability to pests, diseases, and drought) cannot be overcome. Asking why farmers continue to supply themselves with seed, Traoré offers the explanation provided in Box 1, based on history, culture, and traditional knowledge systems.

The Douentza site in this research project offers a counterexample of a case in which village markets played an important role in replenishing farmer seed supplies (see case detailed by Sperling et al. 2006). A flash flood occurred in 2003, followed by a severe drought (late onset and early cessation of rainfall) and an invasion of locusts in 2004 (the worst in 20 years) and a shortage of rainfall in 2005. In 2005, millet harvests were estimated to be 55 percent of the norm. The worst damage in the region of Mopti occurred in the Douentza circle.

The dominant crop in the Douentza site is millet, and farmers prefer their local landraces, which have a fairly narrow range of adaptation (30–40 km). Narrowness of adaptation is explained by the date of flowering as it relates to moisture and by differences in soil type. With respect to rainfall and flowering, varieties originating in the very dry areas are adapted to more humid areas, but not vice versa. Perhaps as a consequence, Sperling et al. (2006) found that traders appear to give unusual attention to distinguishing between seed and grain, and farmers rate the quality of seed they find in village markets as "good." Even in normal times, several resowings may be necessary, so that the study estimates seeding rates of 10–20 kg per hectare for millet and 5–10 kg per hectare for sorghum. Millet is planted first and sometimes dry.

Notably, the Sperling et al. (2006) study concluded that social networks did not contribute significantly to easing seed stress in emergency situations. While gifts and nonmonetized exchanges are the norm (monetized exchanges would be secret), the quantities involved are "symbolic" (Sperling et al. 2006, 49). Villages located in the cliffs are specialized in the production of particularly early-maturing varieties that are valued as seed by farmers elsewhere, and these were sought after and supplied by traders in weekly markets. Even in normal times, the study reports that 10 percent of seed is obtained through weekly markets.

Not all studies conducted in Mali conclude that farmer seed systems are so dynamic, however. A detailed analysis of sorghum seed systems in the regions of Mandé and Diola, in the 700–1,200 mm rainfall zone (a more humid area than either of the sites in this research project) revealed that farmers

rarely obtained seed from other family members, neighbors, or the market, although individual families can keep as many as five or six varieties at a time (Diakité et al. 2003, cited in Weltzien et al. 2006). As suggested by other studies, these authors concluded that selling seed is "taboo."

Nongovernmental Organizations

NGOs support village seed multiplication projects, seed banks, seed fairs, and seed auctions to promote the circulation of both improved and local seed among farmers, in both study sites of this research project and in many villages of Mali. Diakité et al. (2005) describe in particular the activities of the Unitarian Service Committee of Canada (USC-Canada) in the Douentza circle, region of Mopti. Since 1993, USC-Canada has undertaken the construction of local genebanks, multilocational trials, seed fairs and auctions, and seed production. Although the IER collaborates with the project, the seed is not certified.

Bazile (2006) highlights the potential role of a growing movement of voluntary seed producer groups among farmers' associations as a bridge between farmers and the state. Exploiting these links among formal and informal associations could support the promotion and effective distribution of improved seed. He calls for stronger partnerships between research bodies, state services, and village communities and organizations. Since the SSN has difficulty supplying varieties that are specifically adapted to particular environmental conditions, farmers' organizations such as the AOPP can use their extensive community networks to test and evaluate the certified seed of improved varieties. According to Diakité et al. (2005), the AOPP has been involved in producing certified sorghum seed since 2002 in the villages of Sanekuy, Souara, and Torola, circle of Tominian, region of Ségou. Seed demand is estimated at the level of village associations and transmitted to the cereals commission at the national coordination office of the AOPP in Bamako.

In more general terms, Diakité et al. (2005) argue that farmer seed producers and farmers' associations are a crucial link in the seed value chain. With respect to seed producers, they report that 2,627 farmers participated in CSVs from 1989 to 1996. These farmers have been trained over the years in seed multiplication, stocking and conserving seed, use of credit, and banking. The authors state that 11 of the original 20 groups are semiprofessional, although the CSVs are no longer operational because of management problems. The involvement of women and youth in these groups has been limited, although they cite two examples of successful women's groups. The formation of new farmers' associations was stimulated by the recent democratization process in Mali. These include unions and cooperatives, groups with economic interests, and more traditional or customary village associations (*tons*). Programs at the national, regional, and local levels are typically established in consultation with these organizations.

Emergency Relief

Emergency relief has also been a source of seed in Mali, of both improved varieties and landraces. The actors in this channel are those described in the previous subsection. Diakité et al. (2004) conducted a detailed study to follow up on the use of improved millet, sorghum, and cowpea seed originally distributed through emergency relief after the 1997–1998 drought to villages in Koulikoro, Ségou, and Mopti. They were interested in the role of both emergency seed relief and the farmer seed system as mechanisms for diffusing improved seed. Although most varieties in use were local in provenance, marked differences in use of improved varieties were evident among villages: in four villages, the number of farmers growing improved seed had increased; in two, the number had decreased; and in five, improved varieties were lost or abandoned. The seed of varieties that were adopted were incorporated into the farmer seed system. Overall, improved sorghum seed was grown by 18 percent of the farmers the authors surveyed, and improved millet seed was grown by 14 percent. As in Traoré's study (2006), farmers generally planted the seed saved from the previous harvest, originally obtained through inheritance. Diakité et al. (2004) found limited spread of varieties from one village to the next, whether from farmer to farm or through local markets. Purchase in cash was reported for 10 percent of millet seed transactions concerning either local or improved seed, and that percentage is nearly twice as high as for sorghum and three times as high as for cowpea, which is hard to store. Purchases in local markets represented about two-thirds of the cash-based transactions. For most farmers, the principal sources of seed were parents or close relatives, and a lot of improved seed was distributed through gift or barter.

Diakité et al. (2004) point out that although diffusion of improved seed that is appropriate for the local agro-ecology can be enhanced by encouraging more farmers to spread information and provide seed to others, the demand for improved seed in any given locality will decline when it becomes part of a farmer seed system and its cultivation becomes widespread. That point has implications for the economic sustainability of seed multiplication projects in villages, which depends on the capacity of farmers to sell seed to other farmers.

4. PERFORMANCE

The PAFISEM report (FAD 2001) provides a telling critique of performance of the formal seed sector toward the end of the 1990s. According to the report, the annual demand for improved seed of both millet and sorghum is on the order of 1,900 tons, to which can be added a 10 percent security stock. By contrast, the production of certified seed was 230 tons on average for all rainfed crops from 1988 to 1993 and only 32 tons per year from 1994 to 1996. In the later period, the CSVs were indebted, and the credit for commercialization was not renewed. Certified seed covered only an estimated 8 percent of the potential area between 1988 and 1993 and 2–3 percent between 1994 and 1996. Taking all unofficial production and circulation into account, the estimated portion of area covered by improved seed during the period was 15 percent.

Table 3 summarizes several indicators of performance of the formal seed sector for major cereal crops only (Ministère de l'Agriculture 2007). Generally, production and sales of registered (R1) seed are close in magnitude. However, a great disparity exists between seed production and estimated demand. According to the report, this is explained by the fact that demand is estimated each season by agriculture department staff based on orders placed by farmers in the previous season. In several seasons, sales include carryover stocks, resulting in a sales rate exceeding 100 percent.

Table 3. Evolution of R1 seed production, sales, and certification from 1996 to 2006

		Production Season									
Crop	Indicator	1996–1997	1997–1998	1998–1999	1999–2000	2000–2001	2001–2002	2002–2003	2003–2004	2004–2005	2005–2006[b]
Rice	Production (t)	242.57	218.61	290.81	251.79	298.97	349.40	297.82	344.69	373.27	489.04
	Demand (t)	171.93	73.62	150.30	144.82	1.50	8.58	178.36	214.59		
	Sales (t)	190.62	191.62	269.09	248.25	272.50	297.17	367.32		432.61	489.04
	Sales rate (%)	78.58	87.65	92.53	98.59	91.14	85.05	123.33[a]			
	Certification rate (%)	98.11	98.62	88.83	97.41	96.33	97.46	95.61	98.44		
Maize	Production (t)	11.02	15.36	15.03	15.17	15.72	27.64	35.56	104.20	126.03	156.19
	Demand (t)	4.96	5.81	6.75	9.65	17.19	13.64	18.40	1.15		
	Sales (t)	5.91	15.36	15.03	15.17	15.72	27.64	32.50		156.339[a]	156.19
	Sales rate (%)	53.65	100.00	100.00	100.00	100.00	100.00	91.40			
	Certification rate (%)	100.00	100.00	100.00	100.00	100.00	94.80	79.38	99.90		
Sorghum	Production (t)	5.76	13.73	13.43	14.30	16.54	8.00	8.05	19.40	22.18	28.33
	Demand (t)	1.63	4.50	5.50	0.40	0.40	0.50	5.24	0.34		
	Sales (t)	5.42	13.73	12.86	9.65	16.54	8.00	8.05		33.586[a]	28.33
	Sales rate (%)	93.97	100.00	95.76	67.48	100.00	100.00	100.00			
	Certification rate (%)	100.00	100.00	98.58	100.00	98.72	100.00	100.00	100.00		
Millet	Production (t)	5.76	9.42	10.11	12.43	11.32	10.06	10.17	23.55	32.58	41.92
	Demand (t)	1.12	0.14	6.25	7.96	1.20	0.30	5.56	0.40		
	Sales (t)	3.24	9.42	6.93	12.43	11.12	10.06	10.06		50.13[a]	41.92
	Sales rate (%)	56.15	100.00	63.21	100.00	98.23	100.00	98.91			
	Certification rate (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00		

Source: Ministère de l'Agriculture (2007).
Note: Blanks indicate that data were not available.
[a] Carryover stocks were also sold.
All production in 2005–2006 was sold for seed in 2006–2007 or for reconstituting the national security stock. The following quantities (t) were purchased from farmer seed producers: R1: rice (135.76), maize (74.18), sorghum (8.70), millet (11.80); R2: rice (100.33), maize (63.71), sorghum (16.05), millet (7.21).

The estimated rate of increase in seed production over the past decade is large for sorghum (229 percent) but negligible for millet (2 percent). Production of rice and maize seed is much greater than for sorghum and millet, the rainfed cereals. The proportion of production sold varies by year but averages 93.9 percent for sorghum and 88.1 percent for millet. The proportion of seed produced that is of good enough quality to be certified is good, especially compared with that of cowpeas or groundnut (not shown in the excerpted Table 3).

Annual seed demand is estimated using two types of information: last year's rate of use and the stated preferences of farmers by crop and variety, as transmitted through the actors in the formal channel. The SSN assembles the information with a 5–10 percent provision for flexibility. Clearly, as noted by Diakité and Diarra (2000), farmers' plans can change when planting time arrives based on seed prices, cash constraints, or expectations of weather conditions. In addition, seed may not be provided in time for planting. Moreover, information is no longer collected systematically at the farm level, nor is it transmitted effectively, resulting in a poor understanding of effective demand (Diakité, pers. comm.).

Still, there is little evidence that total production of certified sorghum and millet seed is sufficient to cover more than a small percentage of crop area. Table 4 combines the production of R1 seed reported in Table 3 with estimates of certified (R2) seed production and areas planted to sorghum and millet over the past decade. With a seeding rate of 5 kg per hectare (no replanting), certified seed sold in each year covered 1–2 percent of the millet area and 2–7 percent of the sorghum area. If farmers replaced their certified seed in the fourth year, these estimates suggest that the area covered by improved millet seed was about 5–9 percent of the area planted to the crop and 8–18 percent for sorghum. The percentage of farmers growing improved seed is generally higher than the percentage of area covered because farmers often grow seed of both improved varieties and landraces. Percentages would also be higher for zones with high productivity potential, more commercially oriented farmers, and better infrastructure.

Table 4. Estimated use of certified sorghum and millet seed in Mali, 1995–2006

Growing Season	Area Planted to Crop (hectare)	Crop as % of Area Planted to Leading Cereals	Production of R1 Certified Seed (ton)	Production of R2 Certified Seed [a] (ton)	Estimated Area Planted to Certified Seed (hectare)	Estimated Area Planted to Certified Seed (%)	Estimated Area Planted to Improved Seed If Seed Replaced in 4th year (%)
Millet seed							
1996	935,655	46	5.76	72.01	15,555	1.66	4.99
1997	878,941	44	5.763	56.01	12,355	1.41	6.65
1998	910,816	43	9.423	72.01	16,287	1.79	8.06
1999	932,307	38	10.111	86.60	19,342	2.07	8.18
2000	1,078,624	47	12.434	71.70	16,827	1.56	8.85
2001	1,142,388	44	11.322	73.80	17,024	1.49	8.62
2002	1,557,590	49	10.057	94.20	20,851	1.34	8.04
2003	1,888,889	54	10.166	120.20	26,073	1.38	7.82
2004	1,484,190	48	23.547	120.20	28,749	1.94	7.71
2005	1,484,190	48	32.584	38.29	14,174	0.96	8.30
2006	1,472,137	46	19.722	81.56	20,255	1.38	7.88
Sorghum seed							
1996	541,185	27	5.76	70.69	15,291	2.83	8.48
1997	573,034	29	13.73	172.22	37,190	6.49	11.30
1998	616,630	29	13.43	70.69	16,824	2.73	17.79
1999	733,037	30	14.30	82.64	19,388	2.64	17.69
2000	674,768	29	16.54	99.06	23,120	3.43	13.85
2001	702,478	27	8.00	102.03	22,006	3.13	14.55
2002	923,272	29	8.05	130.22	27,654	3.00	15.04
2003	822,331	24	19.40	166.20	37,120	4.51	14.60
2004	744,172	24	22.18	166.20	37,676	5.06	15.99
2005	744,172	24	28.33	70.31	19,727	2.65	18.05
2006	902,682	28	4.02	82.43	17,289	1.92	16.19

Sources: Table 3, Ministère de l'Agriculture (2007), and projections reported in Diakité and Diarra (2000) for R2 seed from 2000–2004.
a Estimates were not available and average for 1995–1998 was used. Major cereals include sorghum, millet, rice, maize, fonio, and wheat or barley.

Moreover, these estimates should in no way be considered as estimates of the extent to which potential demand has been met, since demand depends on agro-ecological, social, and economic factors. What happens if not all seed produced is sold? One of two situations occurs. In the first, R1 seed is produced on seed farms by farmers under the supervision of the SSN. The SSN purchases seed of certifiable quality and stocks it in its stores until sale. Seed not certified remains in the hands of farmers. Seed not sold from the SSN stores is carried over, either for seed or for consumption as grain if it is judged to be no longer viable as seed.

In the second possible situation, R2 seed is produced by farmer seed producers in their villages under the supervision of the SSN. Seed producers are entirely responsible for their output, and they are generally organized in the form of a cooperative association. If their seed meets certification requirements, the association purchases the seed and takes charge of sales, to avoid natural disasters and unintended diversion of sales. Any seed not sold remains in stores at the village level.

Diakité and Diarra (2000) also report a low level of production of foundation seed, which they attribute to the difficulties of meeting technical requirements, including isolation of plots and conservation in a cold chamber. The production program for R1 seed has not been strongly linked to the demand for R2 seed that is articulated by development projects, NGOs, and the agricultural staff working with farmers but instead is dictated by the capacity of the SSN branches, which the authors found were underutilized. Most of the certified seed grown by farmer groups is sold directly without passing through the official circuit. The margins they report are barely positive for millet and negative for sorghum. Lack of quality control in the field and laboratory apparently leads to a high rate of rejection of R2 seed. In conclusion, Diakité and Diarra (2000) emphasize the weak links between seed supply and seed demand in the formal sector.

Diakité et al. (2005) examined R2 seed production in greater detail for three cropping seasons based on field studies of the producer groups established under the PAFISEM (2002–2003 through 2004–2005). Both area and production of millet seed declined over the period, which the authors attribute primarily to poor rainfall and poor drought tolerance of the varieties grown. Both area and production of sorghum seed increased over the same period, suggesting that sorghum varieties grown were relatively more tolerant of low rainfall than the millet varieties.

The rate of growth of equipment over the three-year period was highly variable but generally positive, with the exception of the region of Mopti. Of the seed producers surveyed, only 47.5 percent had been trained in seed production techniques, 49 percent stated that they had a knowledge of national seed regulations and legislation, and 46 percent reported some experience with commercialization of seed; the last two percentages varied considerably by region. Thus, Diakité et al. (2005) conclude that lack of training is a major constraint to performance of the seed producer groups.

According to internal PAFISEM documentation, several of the objectives of the project have been met. For example, the laboratory at Sotuba has been rehabilitated and equipped, and four laboratories have been established. The annual security stock of 500 tons of certified seed of rainfed crops has been constituted. Farmer producers of R1 and R2 seed have received credit and have been trained. They are approaching the goals in terms of quantities of R1 seed produced. Buildings and equipment on seed farms have been rehabilitated, and land on the farms has been ceded to farmer seed producers on the basis of three-month renewable contracts. The BNDA has granted sufficient funds to profitable seed enterprises that are paying back on a regular basis. The project is currently in its last year of implementation, with an expectation that it will be continued for an additional year at least.

5. CONSTRAINTS

Major constraints for sorghum and millet seed systems in Mali can be grouped under challenges posed by the production environment and plant breeding and institutional factors that have slowed the process of privatization. These are discussed next.

Production Environment and Plant Breeding

For the Malian agricultural sector in general, the most binding constraint is rainfall, which diminishes sharply from the south to the northern regions and has declined overall during the past 40 to 50 years. Particularly large shocks were apparent in 1972–1973 and 1983–1994 across the Sahelian region as a whole (Matlon 1990). Matlon studied the resource imbalances that emerged in the late 1980s, particularly in the Sudano-Sahelian zone, when population growth and market penetration led to a reduction in fallow periods and expansion into more fragile and less productive soils, accelerated by growing rural markets for consumer goods. In the traditional system for managing natural resources, long bush-fallow rotations supported soil fertility, and intercropping systems made efficient use of labor, the most binding input constraint. Given limited markets and an orientation toward subsistence and risk aversion, there was little demand for nonlabor inputs. Matlon argues that because these exogenous changes were recent and their effects were masked by a secular decline in rainfall, farmers were unable to develop more appropriate production systems.

To these constraints are added a general lack of market infrastructure; the limited supply and high cost of production inputs and equipment, partly because of Mali's landlocked status; and seasonal access only to certain regions of production. The demand for nonlabor inputs in production continues to be a weak, particularly for crops like sorghum and millet.

Under these circumstances, it is fundamental to recognize that breeding improved varieties of millet and sorghum for Sahelian farmers is not easy: "Too much has been expected of breeders" (Sanders et al. 1996, 38). The production environment in much of the savannah is harsh, with soils that are low in organic matter, nitrogen, and phosphorus. International and national research centers accelerated breeding efforts following the catastrophic drought of 1972–1973, but new cultivars in the dry savannahs made little impact on yields. Sanders et al. called this the "failure of the cultivar approach" (29), arguing that technology development needed to be directed toward improved soil fertility and moisture availability as a precursor to the introduction of new cultivars.

Of the improved varieties that performed well on research stations during that period, few performed better than landraces on farms (Matlon 1985). Matlon (1987) identified several reasons, which have since been addressed. First, an emphasis was placed on material that was successful in India but was

not adapted to the high soil temperatures in the Sahel. Breeder selection occurred on the stations, where production techniques were far removed from farmers' practices in their dependence on external inputs. In addition, the tremendous microvariation in climate, soils, and production systems means that stress levels are not only high but also highly variable. Thus, scientists have difficultly anticipating the environments in which they should place their materials for selection.

Low heritability of sorghum and millet in the Sahel makes it difficult to improve the crop and for farmers to recognize the advantages of a new variety. In genetics, heritability is the proportion of phenotypic variation in a population that is attributable to genetic variation among individuals. A phenotype describes any observed quality of an organism, such as its morphology, development, or behavior, as opposed to its genotype—the inherited instructions it carries, which may or may not be expressed. Variation among individual plants in a farmer's field may be caused by genetic and/or environmental factors.

Local sorghum and millet varieties grown in the Sudanian zone have photoperiodicity, which enables plants to adjust the length of the cultural cycle to synchronize with the length of the rainy season. Early selection programs, combined with the effects of drought, led to the gradual elimination of photoperiodism in favor of a range of varieties with short, fixed cycle lengths (Vaksmann et al. 1996). Based on their research, Vaksmann et al. recommended a rapid way to determine whether a cultivar is sensitive to day length and urged that breeders seek to reintegrate the characteristic to better address the needs of farmers. In an analysis that compared 193 ecotypes collected in 1979 and 128 in 1999, Traoré et al. (2000) found that despite the long-term reduction in rainfall, the extreme interseasonal variability in the beginning and end dates of the growing season did not change. Mean cycle lengths of cultivars changed with farmers' selection processes but not as much as would have been the case without photoperiodicity (M. Grum, pers. comm.).

Although improved millet and sorghum varieties (including hybrid sorghum) have been widely accepted by farmers in southern Africa, adoption rates in West Africa remain low for both crops. De Vries and Toenniessen (2001) explain that guinea races of sorghum dominate in the Sudanian zone of Mali and differ from the caudatum and kafir races that make up the bulk of materials in other regions of the world. Because the private sector has not been responsible for seed distribution opportunities, and the public sector has failed to supply improved seed in reasonable quantities, researchers have consistently called for the development of the informal seed system, but how this is to be done remains unclear (De Vries and Toenniessen 2001). While hybrid millet has been very successful in India, prospects for success in Mali are not considered high at present. ICRISAT is currently testing millet hybrids as an approach in northern Nigeria, where markets are more developed and population densities are higher.

According to Weltzien et al. (2006), an assessment of the economic impact of the Sorghum and Millet Breeding Programme in Mali, conducted by ICRISAT in 1996, served as the point of departure for shifting ICRISAT's sorghum-breeding program in West Africa. The study found that farmers' adoption of newly bred varieties, particularly those not resembling the local guinea-type landraces, was very low. The materials adopted by farmers were "almost exclusively purified sorghum landraces, selected from local materials" (59), which, compared with traditional landraces have only a small yield advantage and a primary advantage of a slightly earlier maturity. The new orientation described by Weltzien et al. is to strengthen farmer and community organizations and their links to research organizations, scaling up participatory testing of varieties and decentralized seed production to reduce the time lag between variety development and adoption. ICRISAT's breeding approach involves the diversification of a set of populations based on a range of guinea races. Farmers are involved in the selection of materials on stations. IER has also developed interracial crosses between guinea and caudatum types.

Weltzien emphasizes that past failures of sorghum and pearl millet breeding in Mali should not be discussed in one set of arguments. The reasons for low adoption of improved varieties differ among the crops. Weltzien believes that seed supply has definitely been a constraint in the case of pearl millet, as evidenced by the ICRISAT's ability to sell all the foundation seed it has produced in recent years. The regional exchange of pearl millet germplasm has been limited, the focus on local germplasm too great, and the understanding of the relationships among materials too limited. Weltzien reports that adoption of an older improved variety of sorghum is fairly high in the drier zones at present, but the introduction of Indian and U.S. germplasm continues to hinder breeding (E. Weltzien, pers. comm.).

Touré et al. (2006) state that although research institutions now have good track records in terms of variety selection and release (see appendix tables A.1 and A.2 for lists of varieties released), and breeding stations are located in all the major agro-ecologies, the degree of variability in soil conditions on state farms is high, and irrigation, farm, and seed-processing equipment is inadequate. The authors also express concern at the overall status of human capital with expertise in seed breeding, certification, and dissemination, noting the average plant breeder is elderly, the number of trained seed specialists is small, and opportunities for in-service training are limited.

Institutional Factors

The PAFISEM report summarizes the major constraints to the performance of the seed value chain as (1) inadequate strategies for encouraging the use of improved seed; (2) inadequate organization of commercial channels and failure to deliver all seed produced by farmers; (3) excessive indebtedness of the CSVs, which did not permit the distribution of credit necessary to commercialize R2 seed; (4) the

heaviness of the SSN mission and staff; and (5) poor coordination between the SSN and the Rural Development Operations (Opérations Développment Rurale; FAD 2001).

Most authors assert that the organizations charged with defining and supervising the implementation of national seed policy function poorly. Insufficient professional capacity is one reason. The CNS has both structural and operational difficulties (Diakité et al. 2005). Structural problems result from the absence of private sector actors and farmers on the council, and assembling council members causes operational delays. Moreover, the official catalog of varieties is not updated frequently enough (Christensen and Cook 2003; Diakité et al. 2005). Christensen and Cook note that neither of the two organizations set up to coordinate the National Seed Plan—the CNS and the National Seed Variety Committee—has farmer or private sector representation.

In practice, private actors are visible only in rice and vegetable farming. It is worth noting that the story for rice and horticultural seed contrasts sharply with that of sorghum and millet. Apparently, the commercial nature of production and the importance of qualitative discrimination in the market led farmers to search for varieties that consumers prefer, rather than focusing on yield. In the case of rice, market reforms were effective because the farmers had the technical capacity to respond, whereas other constraints have prevented sorghum and millet producers from responding to the liberalization of product markets (Christy 2006; Dembélé and Staatz 2000).

For crops other than rice and vegetables, the SSN still tells the seed growers what to grow, and the role of private distributors is still unclear. Both the supply and the effective demand for certified sorghum and millet seed appear to be extremely limited, and these low levels of formal exchange do not yet occur through local markets. The various channels available to market improved seeds are the same for the SSN, farmers involved in seed production, extension specialists, and private seed producers. The PAFISEM includes financing for producers, but distributors and purchasers are not included. Further, the project deals only with certified seed, ignoring the actors in the informal seed sector, such as NGOs and farmers' associations.

Although the chain from breeder to certified seed production is well defined, the seed growers association is active, and seed-processing and storage facilities are available to farmers at minimal costs, the chain exhibits a number of economic weaknesses. First, the margins of return for seed producers are narrow and financing of seed production channels insufficient. There are three sources of funds for seed production: the national budget, which finances the wages of public service agents; private funds for private operators (seed importers in particular); and subsidies contributed by donors. None of these sources of funding is stable. For example, no budgetary line exists for monitoring the production of foundation seed. Access to credit remains difficult. In the past, members of many of the CSVs retained a large part of their production on the farm or for distribution to neighbors rather than delivering it to the

group for official distribution. One problem was that liability for debts was collective, according to the PAFISEM report (FAD 2001). The PAFISEM now aims to finance individual producers.

Most farmers in rural areas have no access to agro-inputs of any kind in local village markets, and agro-input dealers are present only in the vegetable seeds market. Although registered dealers sell quality chemicals and have some training in safe handling practices, Touré et al. (2006) note that expired products are sold in local markets and quality control is insufficient. In general, they argue that neither private dealers nor farmers are adequately trained in the use of chemicals. Most imported seed is horticultural, and a model needs to be developed for importation of improved cereal seeds.

The CSVs functioned poorly, and the provision of seed was severely impaired. The groups were not well placed to operate commercially, with each privately producing and distributing seed without the involvement of large-scale Malian businessmen (Christensen and Cook 2003). However, it is not clear how the new system under the PAFISEM will function in a dramatically different way. This proved to be a fatal flaw in the earlier program, and there is no reason to expect that it will not be today (B. Dembélé, pers. comm.). Clearly, the most critical issue for R2 seed producers is mastering commercialization to enable more widespread diffusion of improved seed. The director of the agricultural office of the San circle, Laye Diakité, expressed consternation that the village seed producer associations have such difficulties selling millet and sorghum seed despite that seed is a primary concern of farmers (pers. comm.). Last year, Diakité's office took responsibility for promoting seed sales over the radio, selling more than 2 tons of an improved sorghum variety (CSM 63E) and 1 ton of an improved millet variety. He contrasted the challenges of selling sorghum and millet seed to the ease of selling hybrid maize seed. Hybrid maize seed was sold to cotton farmers who sought to augment their returns by planting a second crop, taking advantage of residual fertilizer supplied for their use on cotton. He and other key informants cited four major impediments. First, most cooperatives do not produce seed of high enough quality to be certified. Second, participating farmers do not have, and cannot necessarily be expected to have, a commercial orientation. Third, by tradition, farmers are uncomfortable selling the seed of millet and sorghum to one another. The fourth impediment relates to the seeding rate and storage conditions for the crops.

Farmers' sluggish demand for certified sorghum and millet seed can be understood in part as a function of seeding rates. In normal seasons, even considering several sowings, only 10–20 kg of pearl millet are required per hectare. Assuming a yield of 500 kg per ton, this amount represents less than 4 percent of a farmer's harvest. For sorghum, the seeding rate is only 5–10 kg per hectare. Unlike the seed of leguminous crops such as cowpea and groundnut, millet and sorghum seed store well for at least one season. If seed needs for these staple crops are so minimal, and seed is so readily available in village stocks and granaries through gift or exchange, or for the price of grain on the local market, why pay for certified seed?

6. POLICY PERSPECTIVES

The process of privatizing the seed industries for sorghum and millet in Mali, the two major rainfed crops and food staples, faces major challenges. With respect to seed policy, several conclusions can be drawn based on the literature consulted and presented in this overview.

There is no consensus on whether lack of effective demand or insufficient seed supply is the foremost constraint to the use of certified sorghum and millet seed in Mali. Effective demand of farmers remains poorly understood. Even if demand is limited, however, it is evident that the supply of certified seed in many rural areas is hard to find. Total supplies of R1 and R2 seed produced represent an estimated 2–5 percent of the area sown to the crops each year. On the other hand, given the agro-ecological and economic constraints of Mali's subsistence growers, the estimated rates of coverage of improved sorghum seed, in particular, are not entirely discouraging.

Access to this seed is an evident problem for most smallholders. Retail trade in certified seed is still absent. For example, in the key-informant interviews conducted in weekly markets of the circles of San, Tominian, and Douentza, there were no visible efforts to supply local traders and agro-input dealers with small seed packs or to link them to seed producer cooperatives (Smale et al. 2007). Clearly, shifting from a state-based system to one with active private sector involvement will require innovative and deliberate strategies, particularly for sorghum and millet.

Another outstanding question concerns the extent to which use of quality seed is constrained by the lengthy process of producing certified seed. Several authors, including plant breeders, have argued for shortening the time to adoption through decentralized testing and less restrictive methods of ensuring quality. Others have proposed that if suitable institutional links and breeding materials are provided, Mali's highly structured farmers' associations could play a major role in promoting demand, because they are socially and economically embedded in rural communities.

Christensen and Cook (2003) differentiate their recommendations for the seed sector based on the characteristics of the crop. For improved varieties (compared with hybrids) of sorghum and millet, they argue that a combination of tradition and economics work against the development of markets. They recommend that three types of subsidized programs be considered: small-packet programs, coupon systems, and lending programs. Small packets would allow farmers to test new varieties at low cost. Certain seed would be promoted, but farmers would be free to redeem coupons for any seed from any dealer acceptable to the managing agency, thus encouraging the development of seed trade in areas where it would not otherwise exist. Such a system would also be useful in promoting truth in labeling or quality-declared seed, which would help spread varieties by allowing local farmers to sell to neighboring villages without violating seed laws. Once information began flowing more smoothly, existing microfinance

associations could receive funds to make loans specifically for seed. Coupons also function for emergencies, in combination with seed fairs and auctions. In general, Christensen and Cook recommend that existing input traders be encouraged to enter the seed business as production volumes organized by the PAFISEM increase.

Christensen and Cook (2003) concur that there is scope for support from donors and NGOs for on-farm testing activities oriented to the design of appropriate packages of seed, fertilizer, and water-retention technologies. Moreover, they believe that the link between research and the farmer–customer needs to be stronger to promote greater progress in variety selection.

Three questions emerge from this review of the evidence. First, do growers of sorghum and millet in Mali actually *need* a more elaborate seed system than what traditionally exists? Based on the evidence, we would argue that petty vendors of seed are present in the local grain markets of the drier zones precisely because farmers cannot rely entirely on their own production or village-based seed systems. Local seed markets are needed. Any augmented system for supplying certified seed would need to distribute varieties with a clear yield advantage because it is so easy to reproduce the seed of sorghum and millet. Given the history of breeding challenges and low heritability, accomplishing this has often been difficult.

This leads to the second and third questions. Does the formal system have any improved attributes to provide? A long list of registered materials and recent breakthroughs described in the section on plant-breeding challenges suggests that it does. More testing in farmers' fields, by farmers, with the more participatory approach currently recommended by the International Center for Research in the Semi-Arid Tropics and Malian farmers' organizations, could provide better answers.

The third question concerns the potential of participatory approaches. These tend to be costly to scale up, but the costs would be borne by farmers themselves through farmer's organizations, such as the AOPP. However, low heritability not only presents breeding challenges but also affects the likelihood that farmers will feel confident enough to tell their neighbors that they have new, improved varieties. At the same time, given the way information moves through social networks in rural Mali, any lack of confidence can be transmitted many times over. This suggests that despite higher costs, participatory, experiential learning may be the only way to convince Malian farmers that it is worth paying for certified seed.

APPENDIX: SUPPLEMENTARY INFORMATION

Table A.1. Pearl millet varieties in the 2002 official catalog, by yield and rainfall in areas of adaptation

Varieties	Yield (tons per hectare)	Rainfall in areas of adaptation (mm)
IBV 8001	1.5–2.5	300–800
IBV 8004	1.5–2.5	300–800
ITV 8003	1.5–2.5	300–800
ITMV	2.5	300–400
Souna 3	1.2–1.5	300–800
HKP ou IRAT P1	1.5–2.5	300–800
IKMV 8201	1.5–2	400–600
Composite Souna x Sanio TC – 88	2	400–600
Pool 6	1.5	400–600
M2 D2	2–2.5	450–650
NKK (Niou Kouniou de Koro)	2–2.5	450–650
Toroniou C1	1.5–2	400–800
Pool 9	1.2	600–800
IRAT P172 ou Synthétique 17/8 Zalla	1–1.5	400–800
Djiguifa	2–2.5	600–900
Mangakolo	1.5–2	800–1200
Benkadinio	2.5	700–900
NBB (Niou Bobo de Bankass)	2–2.5	450–650
M9 D3	2.5–3	800–1,100
M12 D1	2.5–3	1,000–1,200
Sanioba 03	1.5–2	600–900
Guéfoué 16	1.5–2	400–800
Indiana	1.5–2	400–800
Sanioba 23	1.6–2.5	600–1,000
Sanioteli 53	2–2.5	600–1,000

Source: Touré et al. (2006), based on the 2002 official catalog of varieties.

Table A.2. Sorghum varieties in the 2002 official catalog, by yield and rainfall in areas of adaptation

Varieties	Yield (tons per hectare)	Rainfall in areas of adaptation (mm)
Séguifa	3	400–700
Jakunbè	2	400–700
ICSV 401	2.5	400–600
Malisor 84 – 5	2.5	400–600
N'Toko	2	400–800
Malisor 84 – 4	1.2	600–800
Sofila Sigi	2	400–800
Tiématièteli	1.5	600–1000
CSM 415	2	600–800
Dabitinnen	1.7	600–800
Gadiaba	2–2.5	600–800
Tiémarifing	2	700–1,000
Jigi Sèmè	2.5	700–1,000
IPS 0001	2	≥750
Dususuma	2–3	800
Sariaso	2	700–1,000
Kassaroka	2.2	700–1,000
Foulatièba	2.5	1,000–1,200
NTenimissa	2	800–900
96-CZ-FAp-98	2.5	1,000–1,200
Zarra	2.5	1,000–1,200
Seguetana/CZ	1.5–2	600–800
Wassa	2	600–800
Kenikedjè	2	600–800
98-SB-F2-78	2.5–3	800–1,000
Fambè	2.5–3	400–1,000
Tièdjan	2.5–3	750–950
Gnogome	2.5–4	900–1,000
Sofin	2.5–3	500–800
Djèman	2.5–3.5	750–900
Djèmanin	2–3	500–700
Gnoumani	2.5–3	500–700
Sadjè	2.5–3	450–600
Soblé	2–2.5	500–750
Djakèlè	2–2.5	≤700
Kolobakari	2.5–3.5	900–1,000
N'Gno-deni	2.5–3.5	900–1,000
Kolosina	2.5–3.5	900–1,000
Tassouma	2.5–3	750–900
Kolodjan	3–4	900 –1,000
Ansona	2.7–3.8	750–900
Souroumani	2–3	650–750
Soumalemba	2	900–1,200

Table A.2. Continued

Varieties	Yield (tons per hectare)	Rainfall in areas of adaptation (mm)
Kossa	2.5	900–1,000
Tièblé	2.5	800–1,000
Ngolofing	2	700–900
Marakanio	2.8	700–900
Nazongola Anthocyané	2	600–800
Soumba	2.8	600–800
Yakaré	2	600–800

Source: Touré et al. (2006), based on the 2002 official catalog of varieties.

Box A.1. Cultural significance of self-reliance for sorghum and millet seed, San

French	English
L'autoproduction des semences est une stratégie et une pratique paysanne qui est transmise de père en fils. Elle a été développée et intégrée depuis des millénaires par les paysans pour assurer la sécurité semencière dans leurs exploitations. Elle est une règle qui a été instituée par la constitution Manding, *Kurunkanfuga*, élaborée en 1237 par Soundiata Keita (la constitution obligeait les vieux de transmettre aux jeunes leurs expériences et leurs savoirs)…… La pratique offre l'opportunité aux exploitations de sélectionner leurs propres semences et la quantité nécessaire pour leurs besoins pour l'année suivante et souvent les prévisions pluriannuelles. En plus il faut ajouter que l'autoproduction des semences est la finalité de toutes ces pratiques et sources d'approvisionnement en semences identifiées. Quelque soit la source d'acquisition, la semence est testée, exploitée et suivie par l'exploitation dans le champ. En cas de perte des semences due à une mauvaise pluviométrie, à une mauvaise conservation ou autre, le paysan fait recours aux autres modes d'acquisition de semences. Le don de semences est le mode le plus utilisé. Il est synonyme d'entraide. La notion d'entraide en semences en milieu paysan signifie sauver des vies, donner du bonheur à des personnes, à des familles….Au moment de la création d'une nouvelle unité de production, le nouveau chef d'exploitation hérite du père non seulement les semences, mais aussi un ou des champs pour satisfaire les besoins de sa nouvelle exploitation. Il utilise toutes les expériences, les savoirs et connaissances accumulés durant des années auprès de son père. Les semences issues de sa famille sont cultivées et produites chaque année. (Traoré 2006, 37–38)	Self-reliance in seed production is a strategy and farming practice that is transmitted from father to son. The strategy has evolved over the course of centuries by farmers to ensure seed security on their farms and is a rule that was instituted by the first constitution of the Mandinka, *Kurunkanfuga*, established in 1237 by Soundiata Keita (the constitution obligated elders to transmit their experiences and knowledge to youth). The practice offers farmers the opportunity to select their own seed in the quantities necessary to meet their needs in the subsequent season, often based on multiyear predictions. … In addition, production of one's own seed represents the final output of all seed management practices and sources of supply for a given seed type. Regardless of the source of seed, reproducing it on one's own fields enables the farmer to test it and evaluate its utility. When seed is lost because of poor rainfall, poor conservation, or some other reason, the farmer has recourse to other modes of acquiring seed. Gifts are the most common form of seed provision in the village, synonymous with mutual assistance. In farming communities, the notion of mutual assistance in seed signifies saving lives, giving happiness to other individuals and families. … When a new farm production unit is created, the new head inherits from his father not only seed but also fields to meet the needs of the unit. He uses all the experience and knowledge accumulated during the years he has worked alongside his father. The seed that originated in his family is cultivated and produced each year. (Traoré 2006, 37–38)

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